selection of common things discussed under the title, "Molecular Forces and Motions." Here occur discussions of the diffusion of gases, the evaporation, diffusion and capillary action of liquids, crystallization, elasticity and general properties of matter. This introduction covers eight of the seventy-seven sections into which the book is divided, each section containing material enough for one recitation. The order of treatment of the subjects is as follows: Mechanics, Heat, Electricity, Sound, Light. By summarizing at the close of each section the important topics treated therein, and by setting problems which are related to the life of the pupil as well as to the principles of physics, the authors have made a special effort to produce a helpful book. Mathematical expressions are not avoided, but are used only where they are of apparent advantage to the student; indeed this advantage should be the only justification for mathematical expressions in either elementary or advanced physics. The illustrations, in both number and selection, are to be commended. The volume is distinctly a text-book, all of which is to be taught in the year's course in physics, save perhaps some of the numerous exercises which are found at the close of each lesson. The value of the work can only be ascertained by experience in the class room, but the spirit of the authors and their apparent success in applying it in the preparation of this book must commend the text to the consideration of every high-school teacher.

G. W. Stewart

SPECIAL ARTICLES

ANTAGONISM AND BALANCED SOLUTIONS [1]

The term *antagonism* came into general physiology from medicine, where it was used in the seventies by Rossbach, Luchsinger and others to designate the opposing types of physiological action produced by certain chemical substances. Luchsinger, Langley, Sydney Ringer and others applied the term to that type of physiological situation seen in the opposite effects produced by atropine and pilocarpine on the sweat glands. One alkaloid, atropine, stimulated the activity of the gland, the other depressed it, and one effect could be made to partly or wholly supersede the other by the proper adjustment of the concentration and quantity of alkaloidal solutions used. It was found possible to establish physiologically equivalent quantities of each alkaloid which would exactly nullify the action of the other when applied to the tissue, and a given physiological result could be calculated from given quantities of the antagonistic substances. As Luchsinger saw it, the action of these substances was like algebraic *plus* and *minus* and came back to mass action (Massenwirkung) and affinity, a view accepted in effect by Langley and Ringer. In these experiments physiological antagonism meant opposing action on a definite function as a criterion. Contraction of the frog's heart, action of the salivary gland and contraction of the pupil of the eye were examples of such criteria.

In work of this type the antagonists were used in simple solutions applied serially to the tissues in question, and the fact of antagonistic action was demonstrated by the disappearance of the action characteristic of the first substance upon the application of the second substance. The simultaneous application of the antagonistic substances seems not to have been made.

Work of this type developed a number of important differences in the behavior of supposed antagonists. Luchsinger found when the activity of the sweat gland of the cat was used as a criterion that pilocarpine and atropine produced opposite actions and that each was able to efface the other as wave-hollow effaces wave-crest or as algebraic plus effaces algebraic minus. This ability of each to efface the other and to produce the opposite physiological state in either order of application Langley proposed to call mutual antagonism.

This clean-cut, two-way, type of result, however, was not the rule, and for two chief reasons. (1) It was unusual that the action of two substances should cover precisely the same area of function and thus fully oppose each other throughout their effects. As a result,

[1] Published by permission of the Secretary of Agriculture.

one was likely to cause changes in some structure not affected by the antagonist, hence side effects turned up to confuse the issue. This trouble was due to the fact that more than one function was affected and the criterion had thus become complex. (2) A second difficulty arose from differences in the point to which a given action was referred. For example, Luchsinger found that pilocarpine stimulated the activity of the sweat gland of the cat to a point *above* normal activity, while atropine brought it *below* the normal rate. In carefully adjusted doses of physiological equivalents, the resultant action was a normal rate. Here the point of reference was the normal rate of activity and activities could be counted as plus or minus. When, however, Ringer tested the action of atropine and muscarine on the beat of the isolated frog's heart another type of situation developed. When the heart was treated with muscarine the beat sank to zero or near it. When it was treated with atropine depression also resulted, but only to such a degree as to clearly slow the beat. Both were thus depressants, although in unlike degree. When a "muscarine" heart was treated with atropine it was apparently stimulated, since the beat rose to the rate characteristic of atropine, but, with reference to the normal beat, it still remained depressed. When an "atropine" heart was treated with muscarine no change of beat was seen, muscarine being clearly not able to antagonize atropine. Here two substances acting alike as depressants are called antagonists not because one can raise the action above normal or even to it after depression by the other, but because one is able to efface the other and bring up the action to its own characteristic rate. Here the antagonists are both minus quantities with reference to normality and the result is the lesser minus quantity. Ringer called this a case of antagonism; it was not, however, mutual antagonism, since only one was able to replace the other and no opposite physiological state was produced. These two instances are clearly different in important particulars.

A little later, Ringer, working with small organisms placed in salt solutions, introduced still another phase of the problem. The quantitative plus and minus action, seen when the effect exerted on the single function was taken as the criterion, following successive applications of the chemical substances, was replaced by the action produced by a mixture of ions acting on the total organism. Here the effect of substances in simple solutions on the survival time gave the pure effect of each substance. The antagonistic action could not be tested as heretofore by successive exposures to the substances concerned, since death was the point sought in the experiment. Consequently a change of method was introduced by testing the organisms in mixtures of different proportions. A new sort of result appeared also. With a definite function as a criterion, antagonists merely offset each other more or less completely, the range of results being above or below the normal mark according to the magnitude of the stimulating action of one or both of the antagonists. No resultant action seen was more favorable than that of the more stimulating antagonist. A new feature, therefore, appeared when Ringer found that organisms sometimes lived longer in mixtures of salts than in the most favorable of the components. The term antagonism was again extended by Ringer to cover this third type of situation.

The introduction of life or death, the survival time, as the criterion, complicated the problem in at least one important way. Since in a more or less orderly manner, death means that one or more functions break down or cease to correlate. Hence a disturbing influence introduced by a given ion may harm one function and bring about death, another ion may affect an entirely different function and in a quite different way bring about the same visible response. Hence several ions may all be operating in a cell entirely independently of each other as regards function, and bring about an unvarying response. Death is the uniform result following from a variety of types of injury in the organism. Here, all idea of antagonism, as originally defined, may be absent, owing to the possibility that ions may not meet each other in physiological opposition in any one function. With death as the criterion it seems that one is hardly justified in asserting

antagonism unless it can be shown that somewhere in the complex of reactions one or more functions have been oppositely affected by the supposed antagonists. Death gives an unanalyzed result in which antagonisms may or may not have played a part.

The ideal criterion would be a single clear-cut function that by acceleration or by retardation in its activity would give information concerning the way in which definite external factors affect it. It is difficult, perhaps impossible, to carry the physiological analysis thus far, but the use of any one function that gives results capable of quantitative expression simplifies the problem and approaches more closely to certainty that antagonisms do exist. It is not to be understood that the survival time (death criterion) can not indicate antagonism in a rough way, but only that it does not necessarily indicate it.

What, then, is antagonism? In general, the historically established sense in which it came into general usage among physiologists should be retained as long as it clearly covers the idea with which it was associated. As new conceptions enter they should be designated in fitting terms, in order that confusion may be avoided. In the original sense in medicine, antagonists were much the same as antidotes, antagonists being sought for poisonous substances. Here clearly the idea of the physiological effacement of one by the other was generally accepted. Oftentimes a restoration to the normal was a result of such effacement, but such was not necessarily the case in order to have antagonism. Sometimes, each of the antagonists could efface the other and produce the opposite physiological state, illustrating mutual antagonism, but more frequently one antagonist only was able to efface the other, illustrating simple antagonism. The work developing these results was based on the serial application of the solutions to the organ. We are now confronted with the fact that, in mixtures of salts, the growth rate, survival time, or quantity of ions absorbed, as possible criteria, is found to exceed that observed in the sum of the actions of the constituents in unmixed solutions.

If we recur to Luchsinger's conception of algebraic plus and minus we interpret the frequently observed increment above the expected result not only as indicative of the physiological effacement of one constituent by the other, but as indicative also of an effect beyond simple physiological opposition. It is antagonism in the historic sense of animal physiology plus something else. By Osterhout this increment over the results to be expected on the basis of the effacement of the effect of one antagonist by that of the other, the "something else," is proposed *as a measure of antagonism.* It seems to the writer that this effect comes not from the physiological opposition of the constituents, but rather from their cooperation in the cell in affecting favorably the total balance of cell activities. It is hard to see in this favorable action merely an expression of physiological opposition; it appears much nearer to the "synergism" of the older physiologists, a term used to designate physiological cooperation as opposed to antagonism.

In our present uninstructed condition concerning the activities at play in the living cell, it is hard to see how any scheme can at this time be proposed by which we can designate the degree in which ions entering the plant come into physiological opposition in the manifold functions likely to be affected by them. The result obtained by the investigator is the resultant of an indefinite number of interactions on few or many functions, and we can not assess its separate antagonisms and "synergisms." We are only able to say whether this result is above or below that obtained in the control medium. This control medium may furnish merely a fixed point for comparison or it may in addition also furnish an expression of normality.

In sea water we have the interesting case of a balanced solution, a mixture of salts, each by itself toxic in the concentration present in the natural medium, but in the mixture seen in the sea water, not only capable of sustaining life, but of nourishing marine organisms in so far as the ash constituents go. It is evident, since the individual constituents cause death under circumstances hardly explicable on the basis of nutritional failure, that we have here a group of antagonisms and synergisms so

operating that all functions are sustained in effective cooperation. Not only do the different salts mutually offset each other's physiological deficiencies, but they are able to offset the usually harmful action of the solvent. Loeb has found an interesting experimental subject in *Fundulus,* a fish which is at home not only in the complete mixture, but which likewise survives for a time in distilled water. In the case of organisms which survive indefinitely in distilled water, it is likely that many do so largely by virtue of the salts contained in their own bodies. In general it appears that pure water extracts ions more or less rapidly from many plants and animals, and in case the experimental organism in question is of considerable size and the volume of water sufficiently limited the medium may easily get enough ions from the experimental plant or animal to offset the harmful action of the pure water. The ability of *Fundulus heteroclitus* to part with considerable quantities of salts to fresh water without immediately evident injury has been shown by Sumner. This fish is, however, hardly typical of marine organisms as a whole. In the red algæ, incomplete mixtures are injurious, as in *Fundulus,* but, unlike it, they are promptly killed by distilled water, which for them must be listed with the other constituents which, taken individually, act as fatal poisons. In this case, the mixture of salts is required to antagonize or efface the action of the water. A harmful action has been shown to characterize distilled water when used as a medium for various land plants as well, and to antagonize or efface this harmful action certain mixtures of salts, strikingly reminiscent of sea water in many important points, the so-called nutrient solutions, were long since devised by Knop, Sachs and others. It has been shown more recently by Osterhout and others that the so-called nutrient salts are toxic to land plants when taken individually in much greater dilution than has been generally supposed.

In both sea water and the more or less dilute nutrient solutions present in the soil, normal life is sustained as a rule only in mixtures of proper proportions and necessary concentration. Since salts are required in both cases to overcome the harmful action of pure water, as well as that of the salts themselves, there seems to be no reason to seek to limit the use of the term "balanced solutions" in the manner suggested by Loeb and Osterhout. Unless we admit that malnutrition due to a deficiency in nutrient salts is a form of toxicity excited by the substances present, we can hardly escape the alternative proposition that the missing salts are injurious *in absentia.*

Rodney H. True
Bureau of Plant Industry,
U. S. Dept. of Agriculture

ON THE OSMOTIC PRESSURE OF THE JUICES OF DESERT PLANTS

In 1907 Drabble and Drabble[1] argued from a series of plasmolyzations of the leaf cells of a number of British plants from a range of habitats that physiological dryness of the substratum is the primary factor in the determination of the osmotic strength of the contents of the leaf cells of flowering plants. About four years later Fitting[2] applied the plasmolytic method in an extensive reconnaissance physiological study of the vegetation of the rocky peaks and slopes of the Chaine de Sfa and the adjacent lowlands, comprising concentrated salt marsh and arable oasis. Here he reports some enormously high concentrations of cell sap, such indeed as would theoretically give pressures of over 100 atmospheres if confined in suitable semipermeable membranes surrounded by pure water.

The results of these two papers force upon one the conviction that observations of the concentration of the cell sap may form a legitimate, and indeed essential, feature of comprehensive and thoroughgoing ecological or phytogeographical study.

One must note, however, that the number of observations from each habitat studied by Drabble and Drabble was small, and that their maximum intensity of dryness was not very great. Again, there is no satisfactory series of determinations of the osmotic pressure of the sap of mesophytic plants to serve as a

[1] Drabble and Drabble, *Bio.-Chem. Jour.,* 2: 1907.

[2] Fitting, *Zeitschr. f. Bot.,* 3: 1911.